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JADS End-to-End Test- The Final Chapter

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ABSTRACT

The End-To-End (ETE) Test, conducted under the auspices of the Department of Defense Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E), developed a synthetic test environment using simulations connected by satellite that can be used for future testing, training and doctrinal development. This synthetic environment was used initially to assess the feasibility of using distributed simulation to conduct developmental and operational testing of the Joint Surveillance Target Attack Radar System (Joint STARS). As designed and built, it may be used to conduct future testing of systems such as the Block II Joint STARS, the common ground station (CGS), the All Source Analysis System (ASAS), and the Block II Army Tactical Missile System (ATACMS).

The final chapter of the ETE Test was the Phase 4 advanced distributed simulation (ADS)-enhanced operational test (OT). Phase 4 consisted of three flights of the Joint STARS E-8C over Fort Hood, Texas. During the flights, the aircraft conducted radar surveillance of a battlefield consisting of Fort Hood and its environs and eastern Iraq. The synthetic environment, represented on the radar screens, consisted of 10,000 virtual entities involved in a battle in Iraq and numerous real entities located at Fort Hood. The virtual battlefield was generated by the U.S. Army Training and Doctrine Command Analysis Center (TRAC), White Sands Missile Range (WSMR), New Mexico, using Janus. Radar images observed on the aircraft consisted of real, virtual, and mixed images displayed simultaneously on the operator workstations. All radar data were transmitted to Army ground stations and further processed by the Army's ASAS. Targets were chosen based upon the radar data and sent to Fort Sill, Oklahoma, where virtual ATACMS missiles were fired back into the Janus battlefield. The results of these fire missions were than observed by the radar and presented to the ground stations.

This paper will describe the synthetic test environment, the design considerations involved in developing the synthetic environment, the modifications of the distributed interactive simulation (DIS) standards required to accommodate the environment, and the results and lessons learned, to include data collection and verification and validation (V&V) from conducting an ADS-augmented live test.

End-To-End Test Overview

A previous shortfall in the testing of command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) systems, especially those using sensor systems that cover a large area of the battlefield, such as Joint STARS, was the inadequate numbers of forces, either friendly or adversary, available to realistically portray the expected operational environment. In addition, systems were often tested in isolation without the complementary suite of other command, control, communications, computers and intelligence (C4I) and weapon systems with which to interact. The original *Joint Surveillance Target Attack Radar System (Joint STARS) Multiservice Operational Test and Evaluation (MOT&E) Plan,* dated 21 February 1995, identified the ability to test the requirement for Joint STARS to provide support to a notional corps area of interest as a limitation of the test. As stated in the plan, the testing of this requirement "would require both a completely equipped corps operation/exercise and multiple E-8 aircraft."

Obviously, the requirement for a completely equipped corps operation/exercise was impossible to meet in 1995 and is even more impossible now. Plus, even if the testers could find a fully deployed corps involved in an operational mission, as was roughly the case in Bosnia, there would still be difficulties in collecting data on how well Joint STARS supported the execution of attacks against detected targets.

This test limitation was the major basis for the development of the JADS ETE Test. The JADS ETE Test was designed to add an augmented operational environment, approximating a notional corps area of interest, and a complementary suite of C4ISR and weapons systems with which Joint STARS would interact.

The test concept was to use ADS to supplement the operational environment experienced by the E-8C and light ground station module (LGSM) operators by adding approximately ten thousand additional entities to the battlefield seen by Joint STARS. Also, by adding additional elements of the C4I systems that Joint STARS interacts with and a weapon system, the ATACMS, to engage targets, the test team could evaluate the complete battlefield environment from target detection to target assignment and engagement. It also allowed the tester to evaluate the entire thread, or the individual contribution of any of the parts, and to evaluate what effects an operationally realistic environment had on the system under test.

Several components were required to create the ADS-enhanced operational environment used in the ETE Test. In addition to Joint STARS, the ETE Test required a simulation capable of generating thousands of entities representing the rear elements of a threat force. For this purpose, the ETE Test team selected the U.S. Army's Janus simulation.

Also, a simulation of the Joint STARS radar, called the Virtual Surveillance Target Attack Radar System (VSTARS), that simulated both moving target indicator (MTI) radar and synthetic aperture radar (SAR), was developed to insert the simulated targets into the radar stream within the laboratory or on board the E-8C while it was flying a live mission.

The ETE Test consisted of four phases. Phase 1 developed or modified the components that allowed the mix of live and simulated targets at an E-8C operator's console and LGSM operator's console. Phase 2 evaluated the utility of ADS to support developmental test and evaluation (DT&E) and early operational test and evaluation (OT&E) of a C4ISR system in a laboratory environment. Phase 3 moved components of VSTARS onto the E-8C aircraft, ensured that the components functioned properly, and checked that the synthetic environment properly interacted with the aircraft and the actual LGSM. Phase 4 evaluated the ability to perform test and evaluation (T&E) in a synthetically enhanced operational environment using typical operators.

The first two phases have been previously reported on at last year's workshop [*ETE Update - ADS Testing of C4ISR Systems*]. This paper will cover the final two phases of the ETE Test and the results obtained.

ETE Test Synthetic Environment – Phase 3 Transistion

ETE Test Phase 3 migrated certain software components of VSTARS, specifically the air network interface unit (ANIU) and the radar processor and integrator (RPSI) from the laboratory Alpha workstations to the primary mission equipment on the E-8C aircraft. In addition, the ground network interface unit (GNIU) software was separated from VSTARS and migrated to an Alpha workstation collocated with a satellite transceiver.

Once the migration was completed, each component was tested in isolation and then tested as a part of the complete environment. Specifically, the network to GNIU link was tested verifying that the GNIU was issuing a VSTARS data packet for each protocol data unit (PDU) received. The GNIU to satellite transceiver to satellite transceiver to ANIU was also tested verifying that VSTARS data packets were received. Finally, the ANIU and RPSI were tested using primary mission equipment in the laboratory verifying that they processed the data and generated the appropriate radar reports. Once all components

were shown to be working, the software was moved to the aircraft (T3). The entire environment was then tested using PDUs generated at TRAC-WSMR, sent to Northrop Grumman, and then sent via satellite to the aircraft.

Phase 3 testing at the Northrop Grumman node was conducted in four steps culminating with the transition of the ANIU and RPSI to the test aircraft. Following this transition, a series of system integration tests (SIT) were conducted by the Joint STARS Joint Test Force, and a complete V&V of the RPSI was conducted by Northrop Grumman with ETE Test V&V team oversight.

The SITs were conducted using the T3 aircraft and a medium ground station module (MGSM). They determined if the software changes and additions made to the radar build in any way affected the performance of the radar and operator workstations. The V&V ensured that the ADS-enhanced radar system met the requirements and acceptability criteria established by the ETE Test team.

ETE Test Synthetic Environment – Phase 4 Live Test Version

One of the mandated requirements for the operational testing of C4ISR systems, such as Joint STARS, is that the actual system will participate in the test. It is not, nor has it ever been, the intention of JADS to replace live testing with ADS. Rather, our intent has been to supplement, or enhance, the live testing with an ADS-enhanced test environment that more closely represents the actual operational environment the system will experience when operationally deployed.

The Phase 4 synthetic environment consisted of the same synthetic environment as was used during Phase 2 with the exception that an ADS-enhanced E-8C was used. The radar simulations used in VSTARS during Phase 2 were moved to the aircraft and operated concurrently with the onboard radar. The data on the 10,000 virtual targets were sent to the aircraft using satellite communications (SATCOM). This enabled the aircraft, while flying over Fort Hood, Texas, to observe live, mixed and virtual MTI radar. The operators could also observe virtual and real SARs. These radar reports were then transmitted to the ground and received by an actual light ground station module and common ground station. The sensor-shooter-sensor loop was then followed with the results of the ATACMS missile strikes being observed (survivors displacing and hulks remaining) by the surveillance operators and intelligence analysts.

The operational testing conducted during Phase 4 consisted of three live trials using an ADS-enhanced test environment and five laboratory trials using the Phase 2 synthetic environment. All trials were more than five hours in duration with the exception of the last live trial, which was curtailed because of the nonavailability of tanker aircraft. The lab trials filled in the test scenarios that we were not able to execute because of the lack of test sorties and repeated, for comparison purposes, the scenarios executed during the live trials. Subsequent comparison of the live trials and the lab trials revealed no difference in the surveillance operators and intelligence analysts actions with regard to the virtual targets. During the second live trial, instrumented vehicles and radar reflectors were placed at Fort Hood, and JADS verified that the actual radar's performance was not affected by the ADS-enhanced test environment.

Verification and validation was conducted during both Phase 3 and Phase 4. Details on this V&V is contained in a separate paper [*Verification and Validation of the JADS End-To-End Test-The Final Chapter*] to be presented at this conference.

The ETE Test had the following objectives.

JADS Issue 1. What is the present utility of ADS, including DIS, for T&E?

JADS Objective 1-1. Assess the validity of data from tests utilizing ADS, including DIS, during test execution.

JADS Objective 1-2. Assess the benefits of using ADS, including DIS, in T&E.

JADS Issue 2. What are the critical constraints, concerns, and methodologies when using ADS for T&E?

JADS Objective 2-1. Assess the critical constraints and concerns in ADS performance for T&E.

JADS Objective 2-2. Assess the critical constraints and concerns in ADS support systems for T&E.

JADS Objective 2-3. Develop and assess methodologies associated with ADS for T&E.

The results of the ETE Test are discussed in great detail in the interim reports on the four phases and in less detail in *The Utility of ADS for C4ISR System Testing* report, which can be found on www.jads.abq.com. For the purpose of this paper, we will consider the results as they apply to OT&E, to include early operational assessment, and to DT&E.

OT&E and Early Operational Assessment

The ETE Test determined that valid system under test (SUT) data could be collected on a complex C4ISR system, such as Joint STARS, both in a laboratory-based ADS test environment and in a live ADS-enhanced test environment. The Phase 2 ADS configuration could evaluate 15 out of 45 effectiveness measures of performance (MOP) (including two MOPs not evaluated during the Joint STARS contingency operations test and evaluation) and all 8 effectiveness measures of effectiveness (MOE). Further, the Phase 2 ADS configuration could be used to evaluate 8 out of 27 ground station module (GSM) suitability MOPs.

The Phase 4 ADS configuration evaluated the same measures as the Phase 2 ADS configuration using the actual components of the system. However, if additional elements (simulated or real) were added to the Phase 4 ADS configuration, it could evaluate all 45 effectiveness MOPs (including two MOPs not evaluated during the contingency operations) and all 8 effectiveness MOEs. Furthermore, the augmented Phase 4 ADS configuration could be used to evaluate the GSM and E-8C suitability MOPs (27 out of 27 suitability MOPs), all of the human factors MOPs, and all of the software MOPs.

ADS can provide a useful tool for the tester in support of early operational testing. A laboratory version of the SUT that performs to specifications can be used, as was the case during the Phase 2 test, to assess early operational effectiveness. If the performance of the simulation can be adjusted, studies can be conducted to determine which performance values have the greatest impact on the operational effectiveness of the system.

DT&E

One of the software tools available to the operators on board the E-8C is an automatic tracker (A-tracker). This tool can automatically track a set of targets designated by the operator based upon radar reports and provide the operator with information about the targets. Northrop Grumman agreed to investigate whether or not VSTARS would be useful in testing the tracker in the laboratory prior to live testing. Prior to the use of VSTARS, laboratory (developmental) testing could only be done on a very limited basis because of the requirement for actual radar reports.

Live developmental testing was also limited because of limited resources and cost. In addition, when live testing was conducted, it used only a limited number of test cases because of the lack of test assets, time, and safety considerations.

The version of VSTARS used by Northrop Grumman to evaluate its DT&E utility was an early version and lacked critical instrumentation required for the evaluation. In addition, it was determined that a higher resolution simulation was required to drive the entities involved in the test. Despite the shortcomings, the experiment indicated that VSTARS was capable of supporting the DT&E of Joint STARS subsystems, such as the A-tracker, provided the instrumentation was added and a different scenario driver was used.

Several observations on the utility of ADS to support DT&E were made.

- Multiple repetitions of the same scenario can be performed without competing for scarce lab resources, test aircraft, and range resources.
- The use of ground-based simulations and hardware offers the potential for enormous cost savings, as compared to a live test with the aircraft.
- Any conceivable test case can be "flown" in the laboratory without worrying about safety or limited assets provided the appropriate scenario generator is available.
- Bad software can be quickly discarded and new software could be tried the next day against the entire suite of test cases.
- Most importantly, when a live test is flown, as it must be, the testers can be reasonably sure that they will get the maximum value from the flight and test conditions.

It must be noted that VSTARS ran on one workstation during this test as opposed to the extensive radar laboratory normally required for developmental testing of the tracker. It truly provided the ability to do desktop testing. Use of the Phase 4 test environment would also allow the tester to test against available live test cases and against normally unavailable virtual test cases, thereby maximizing the use of the test flight.

Detailed information on the ETE Test is available in an interim report for each phase and can be found at http://www.jads.abq.com. (After 1 March 2001, refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd. SE, Kirtland Air Force Base, New Mexico 87117-5558 or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

Lessons Learned

- An ADS-enhanced live test environment using validated simulations can provide more realistic threats and force levels than those offered by conventional tests, i.e., threats/levels otherwise unavailable because of cost restrictions, unobtainable threats, etc.

- C4ISR system testers can tailor the simulation entities operating in the ADS environment to closely reflect the forces expected in operational theaters, thus further increasing the relevance of the collected test data.

- ADS allows testers to have more control over the specific aspects of the scenarios of interest and to expand their test concept and design. A typical constraint to test concept development is the number and types of units readily available for a test.

- ADS technology can easily eliminate the conventional testing disadvantage of insufficient battlespace. For example, the National Training Center occupies about one thousand square miles. In contrast, the battlespace for Phase 2 of the ETE Test was almost ten times larger. In fact, ADS technology is capable of supporting even larger battlespaces.

- Using ADS, testers can conduct more test trials for longer periods of time. During the Phase 2 test, the ETE Test team was able to conduct five test trials, lasting six hours each, within a 5-day period. A maximum of three trials could have been conducted using the test aircraft. If additional shifts of operators were available, the test trails could have lasted longer at little additional cost. Because of scheduling issues, crew rest, and the lack of test aircraft, it would be difficult to extend a live test trial beyond five to six hours on station. During the Phase 4 test, the ETE Test team was able to conduct eight test trials using three live test trials and five laboratory test trials. The laboratory test trials were mainly conducted during the periods between live test trials at little or no additional cost.

- The ETE Test also demonstrated that there are no real technical barriers to using an ADS

environment to provide a realistic test environment for a C4ISR system. This is due to the high reliability of the network architecture underlying an ADS environment and the dramatic increases in computer processing and storage capabilities over the past few years. Rather, the key constraints to ADS testing are the familiar ones of time and money.

- ADS allows the tester to assemble, using models, simulations, emulators, and fielded systems, systems of systems that either have not yet been built or would not exist except in time of war. During the ETE Test, an ATACMS missile was fired at an enemy force based on operationally realistic intelligence collected by Joint STARS and processed by an element of ASAS. This was done using fielded C4ISR systems that were electronically linked and functioning as they would in combat. Army intelligence subject matter experts stated that, to the best of their knowledge, this had never been done before the ETE Test.

- ADS can easily provide models and simulations that represent the threats of today and the threats of tomorrow. All models and simulations of threats, no matter what their fidelity, are data driven. The fidelity is determined by the accuracy and detail contained within the data and the fidelity of the algorithms that use the data to depict the threat. During the ETE Test, the threats used were those currently fielded within the Iraqi Army. They could have just as easily been low observable threats from a future battlefield.

Conclusion

As stated in the JADS report, *The Utility of ADS for C4ISR System Testing*:

> Since all C4ISR systems contain the same basic elements (e.g., sensor(s), sensor platform(s), command and control elements, communication lines, and computer hardware and software), the extension of the ETE Test results to other possible C4ISR applications is relatively straightforward. ADS technology allows the evaluation of human-in-the-loop actions, decision processes, timelines, and interoperability which digital simulations do not model well. Using ADS, a mission-level scenario model can be linked to actual C4ISR hardware and software with tactical operators-in-the-loop and tactical communications links for realistic testing in force-on-force scenarios which cannot be accomplished in live testing.
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> ADS is not just of value to C4ISR T&E but can be applied throughout the system acquisition life cycle. In fact, the benefits of using ADS are best realized over the life of a program. ADS is an enabling technology for Simulation Based Acquisition (SBA) and the Simulation, Test, and Evaluation Process (STEP) as applied to C4ISR systems, since these systems are naturally distributed by nature.

Future uses of ADS currently being discussed are a follow-on test of the CGS, the operational test for the Block 20 E-8C (computer replacement program), and operational testing of the Block II ATACMS missile. All these programs are currently investigating the use of VSTARS and elements of the ETE Test synthetic environment.

Gary J. Marchand was the technical lead for the End-to-End (ETE) Test of the Joint Advanced Distributed Simulation Joint Test Force. He was the principle designer of VSTARS and the synthetic environment used for the ETE Test. He received a bachelors degree from the United States Military Academy and an Master of Science Degree in Applied Science from the University of California at Davis. He retired from the U.S. Army in 1993 after having been the deputy director and senior military analyst at the U.S. Army Training and Doctrine Command Analysis Command, White Sands Missile Range. He is currently employed as a senior analyst by Science Applications International Corporation (SAIC).